

Estimating Mixing Patterns for the United States

Sara Del Valle

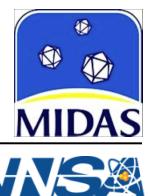
Sue Mniszewski, Geoffrey Fairchild, Kyle Hickmann,
Mac Hyman, & Reid Priedhorsky

Los Alamos National Laboratory



Operated by Los Alamos National Security, LLC for NNSA

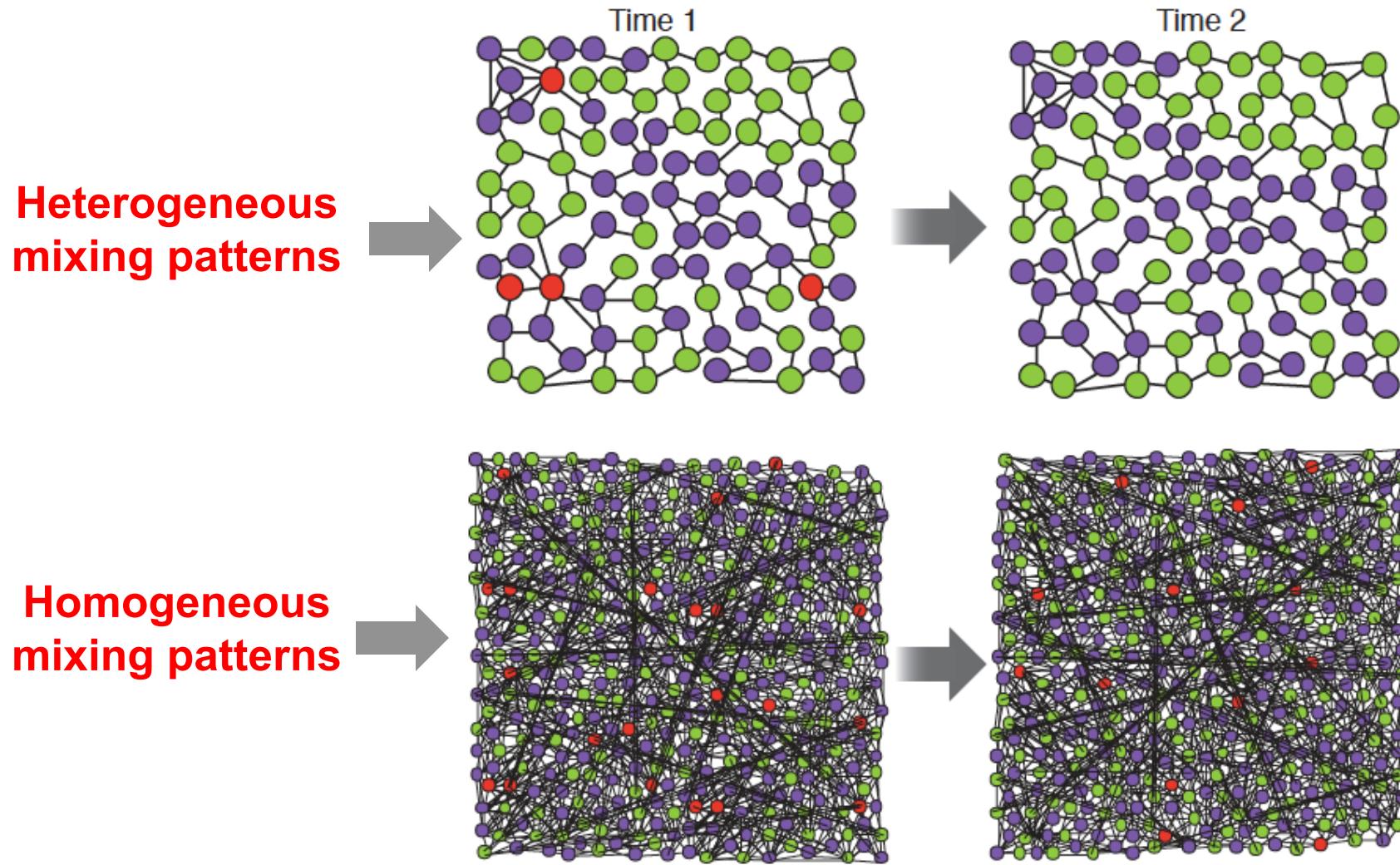
UNCLASSIFIED



Motivation

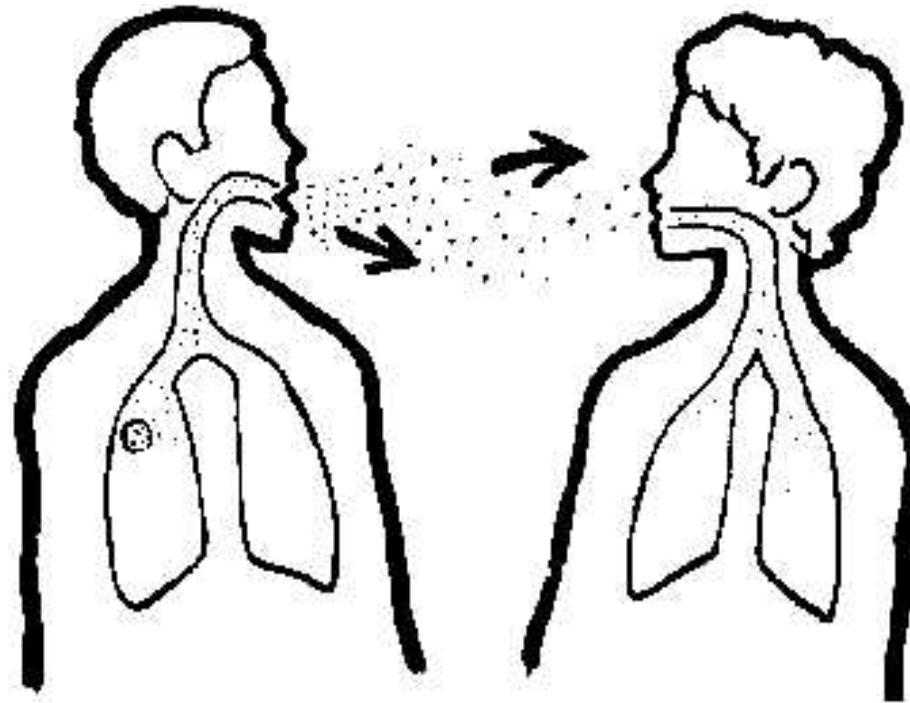
- Populations are heterogeneous in nature
- To accurately capture disease spread:
 - Susceptibility (e.g., genetic predisposition)
 - Infectivity (e.g., pathogen characteristics)
 - Behavioral responses (e.g., mitigations)
 - **Contact patterns**

Heterogeneous vs Homogeneous Contacts



Koopman J. Controlling Smallpox. Science 2002; 298: 1342 - 1344.

Respiratory Infections



How can we estimate human contact patterns?

Empirical Studies

■ Surveys

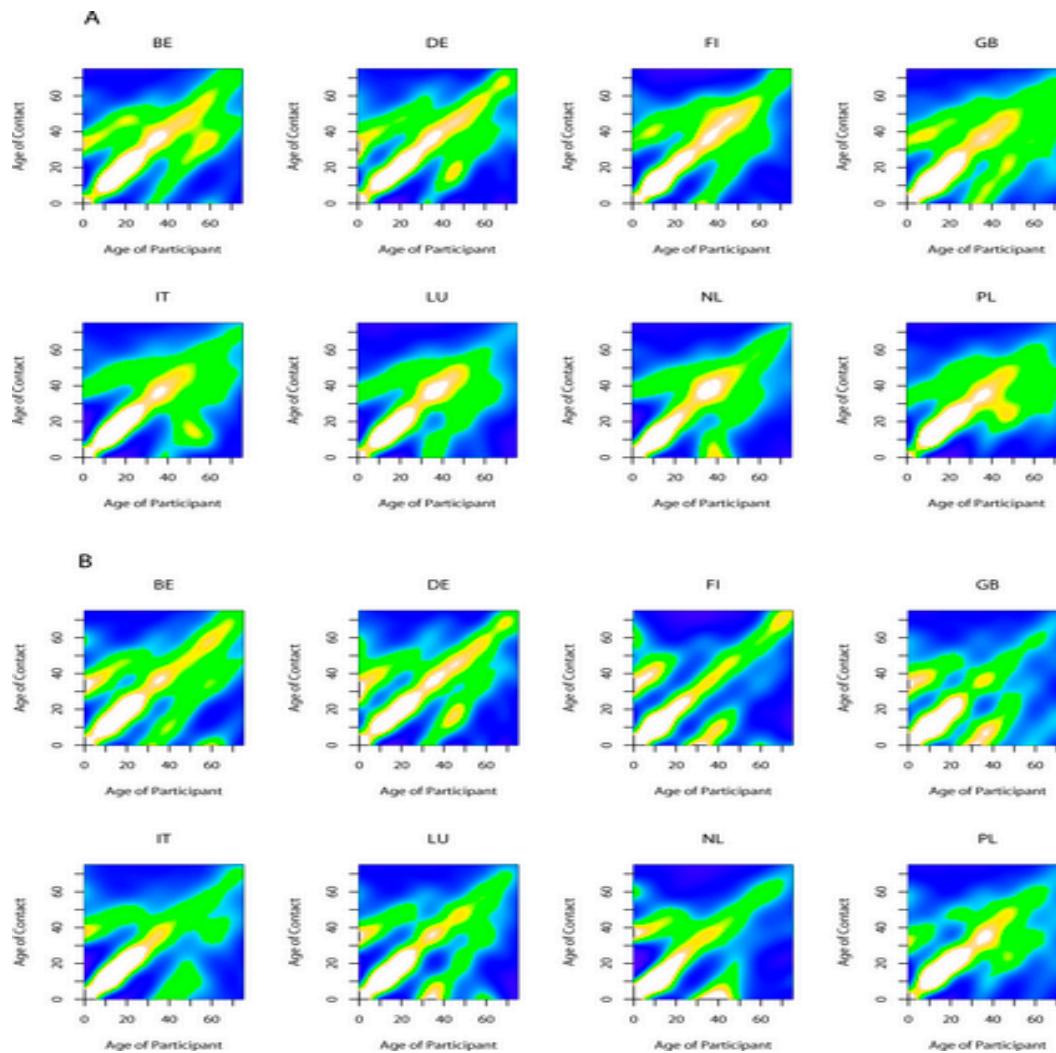
EXAMPLE

This is an example of how somebody might fill in one page of the diary

Age (or range)	Gender F M	Did you touch his/her skin? Y N	How often do you have contact with this person in general?					Where did you have contact? (tick all which apply on your assigned day)					Total time spent with person during whole day				
			Daily or almost daily	About once or twice a week	About once or twice a month	Less than once a month	Never met before	Home	School / Work	Transport	Leisure	Other College	Under 5 mins	5-15 mins	15 mins – 1 hr	1 – 4 hrs	More than 4 hrs
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25(- 30)	✓ □	□ □	□	□	□	✓	□	□	□	□	□	✓	□	□	✓	□	
25(- 29)	✓ □	□ □	□	✓	□	□	□	□	□	□	□	□	□	✓	□	□	
30(- 35)	□ □	□ □	□	✓	□	□	□	□	□	□	□	□	□	✓	□	□	
35(- 40)	□ □	□ □	□	□	✓	□	□	□	□	□	□	□	□	✓	□	□	
35(- 39)	✓ □	□ □	□	□	□	✓	□	□	□	□	□	□	□	✓	□	□	
40(- 42)	□ □	□ □	□	□	□	□	✓	□	□	□	□	□	□	✓	□	□	
42(- □□)	□ □	✓ □	□	□	□	□	✓	□	□	□	□	□	□	✓	□	□	
40(- 45)	□ □	□ □	□	□	□	□	✓	□	□	□	□	□	□	✓	□	□	
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Mossong et al. Social Contacts and Mixing Patterns Relevant to the Spread of Infectious Diseases. PLoS Med 2008.

Figure 3. Smoothed Contact Matrices for Each Country Based on (A) All Reported Contacts and (B) Physical Contacts Weighted by Sampling Weights



Mossong et al. Social Contacts and Mixing Patterns Relevant to the Spread of Infectious Diseases. PLoS Med 2008.

Theoretical Studies

- Proportional mixing

$$c_i = \frac{a_i N_i}{\sum_{j=1}^k a_j N_j}$$

Average per capita contact rate
Group size

- Preferential mixing

Preferred contacts Rest of contacts

$$c_{ij} = \varepsilon_i \delta_{ij} + (1 - \varepsilon_i) \frac{(1 - \varepsilon_j) a_j N_j}{\sum_k (1 - \varepsilon_k) a_k N_k}$$

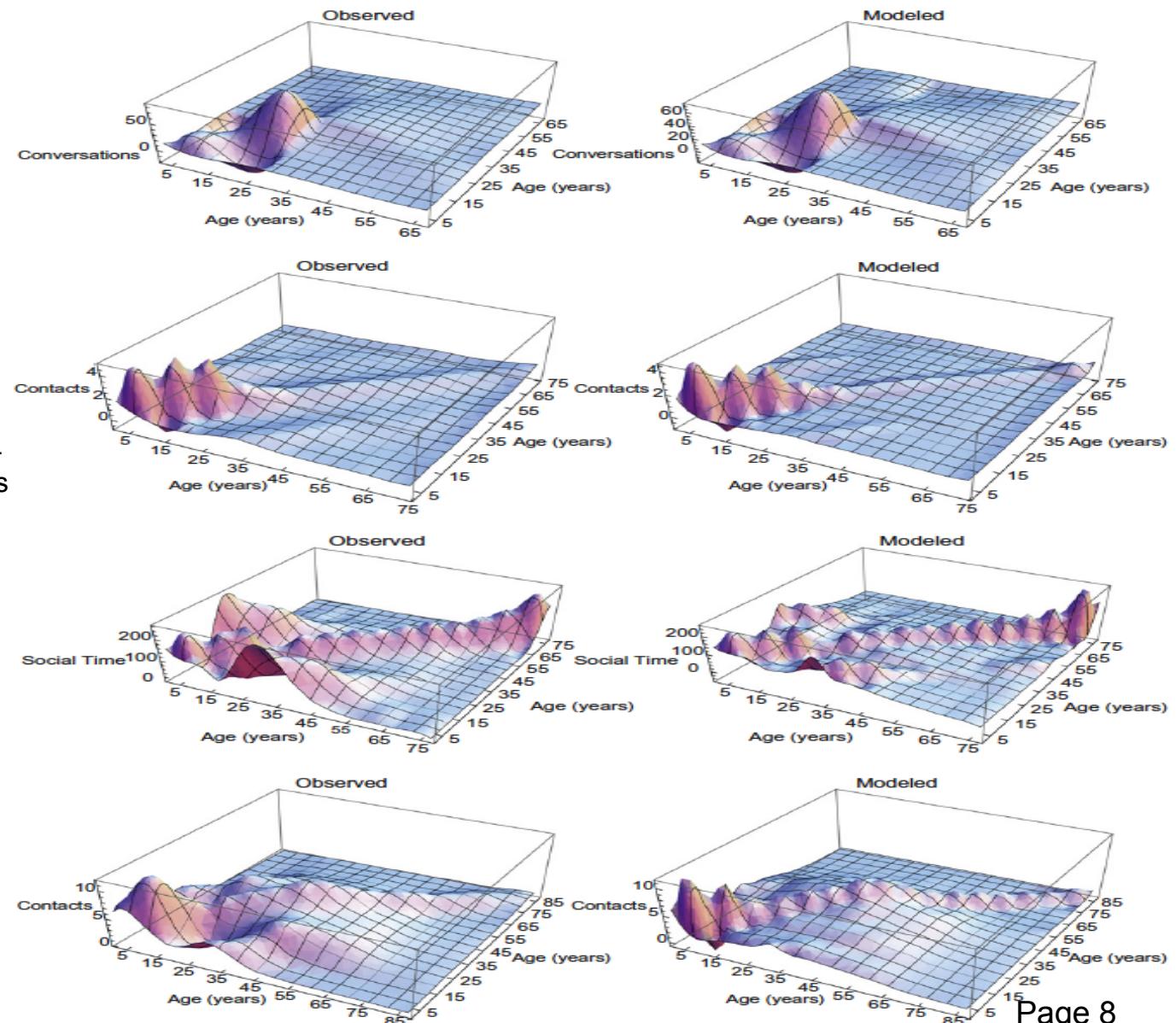
- Refined formulae

$$c_{ij} = \phi_{ij} + (1 - \sum_{l=1}^4 \varepsilon_{li}) \frac{(1 - \sum_{l=1}^4 \varepsilon_{lj}) a_j N_j}{\sum_{k=1}^n (1 - \sum_{l=1}^4 \varepsilon_{lk}) a_k N_k}$$

- Parents & children
- Co-workers
- Contemporaries

Glasser et al. Mixing in age-structured population models of infectious diseases.
Mathematical Biosciences 2012; 235: 1 – 7.

Figure 3. Interpolating functions fitted to geometric means for Wallinga 2006, Mossong 2008, Zagheni 2008, and Del Valle 2007.



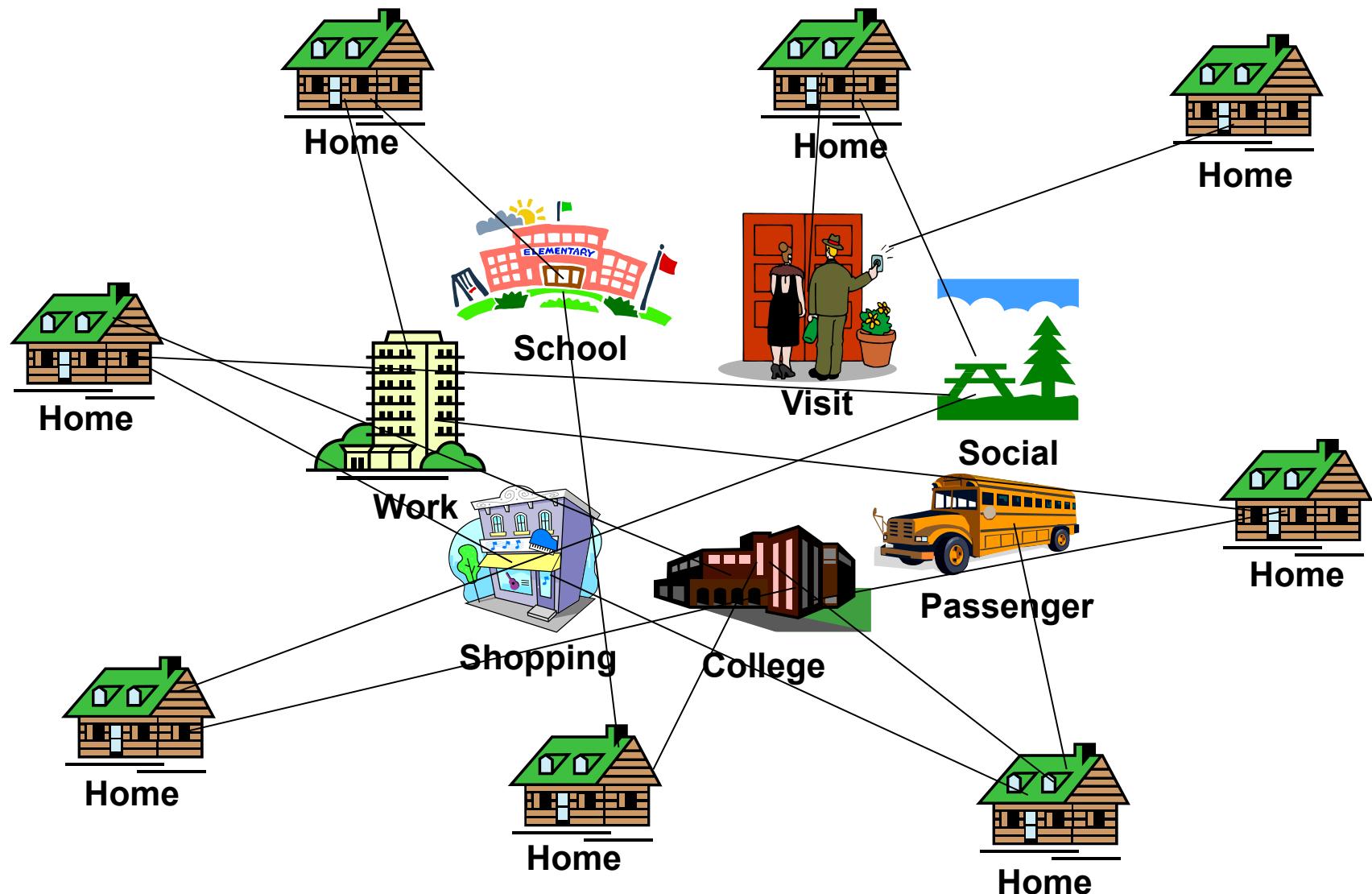
Glasser et al. Mixing in age-structured population models of infectious diseases.
Mathematical Biosciences
2012; 235: 1 – 7.

Simulation

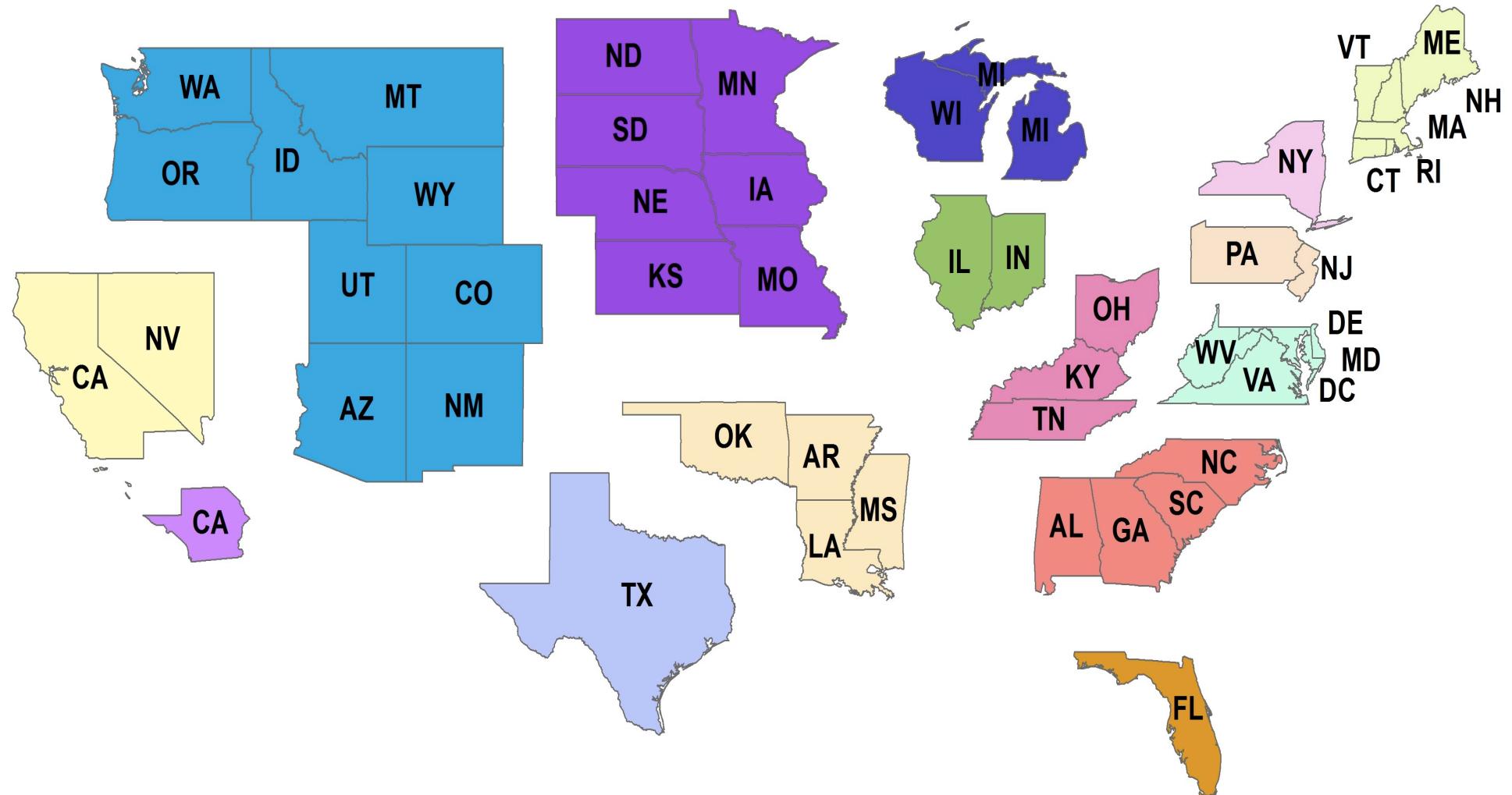
“Previously, scientists had two pillars of understanding: theory and experiment. Now there is a third pillar: **simulation**,”

U.S. Secretary of Energy Steven Chu.”

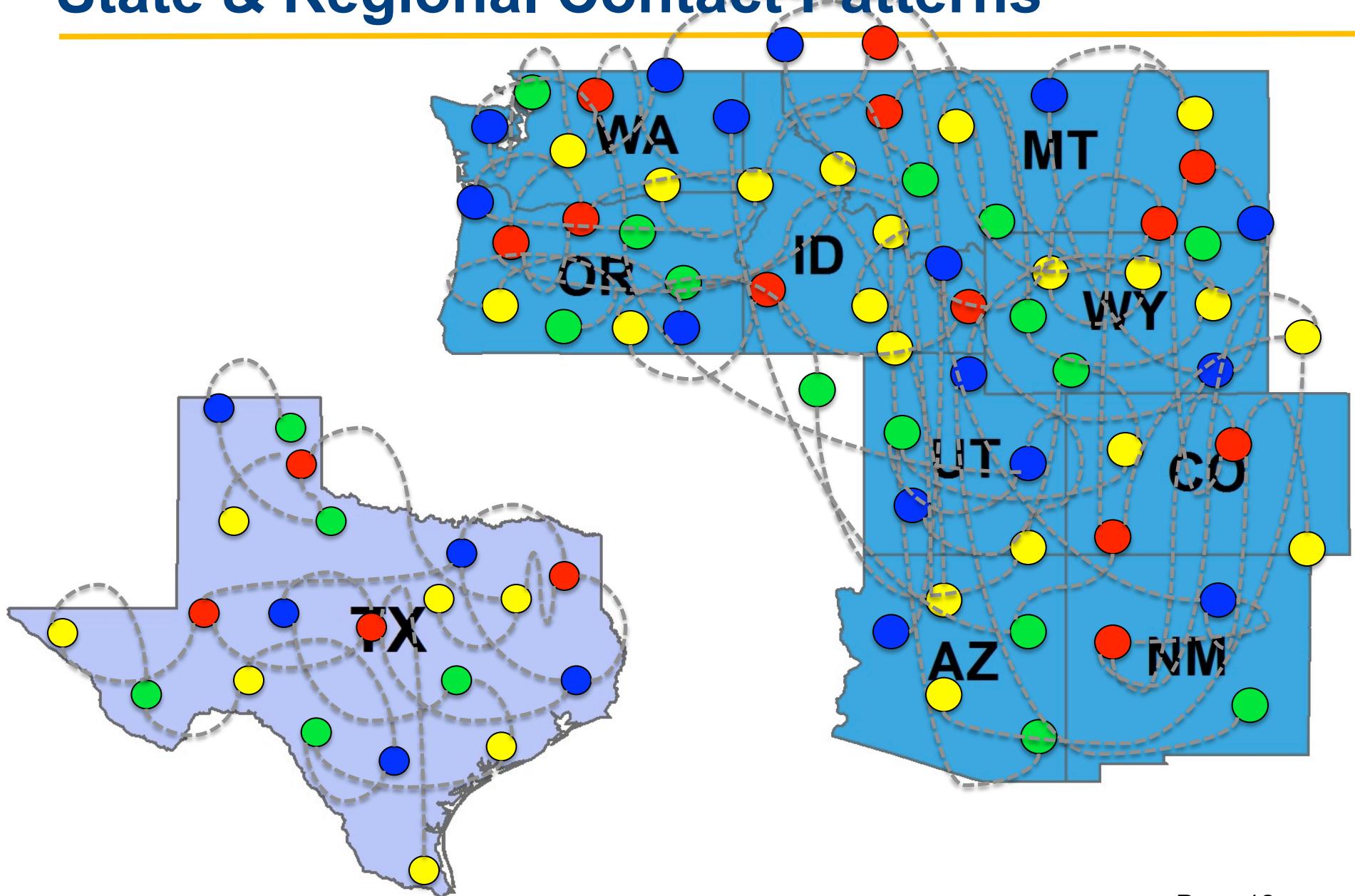
Agent-based Simulation



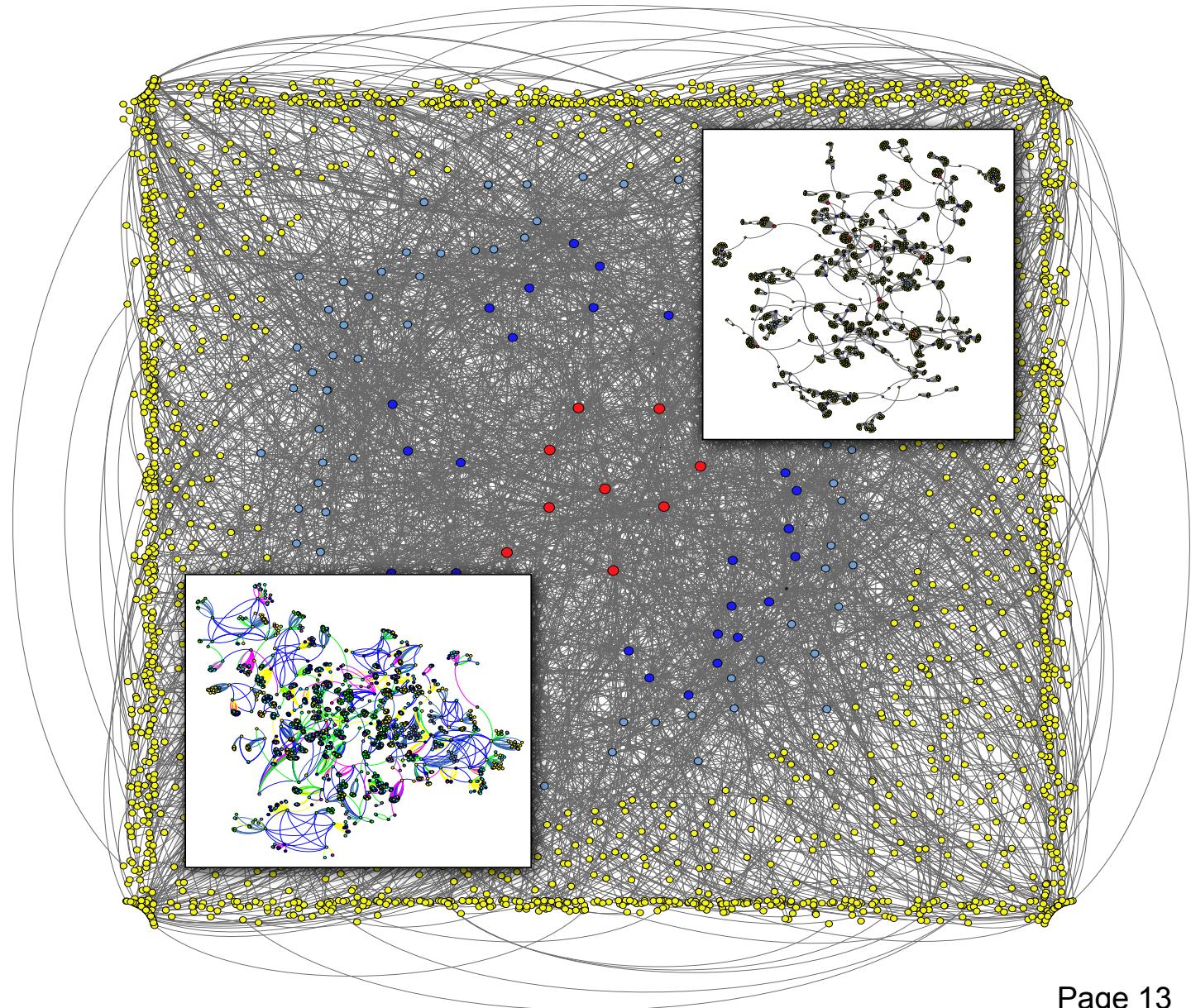
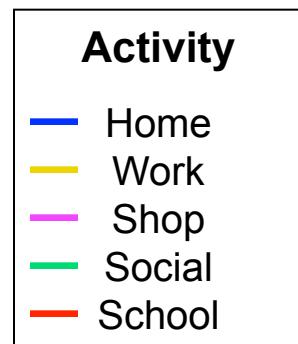
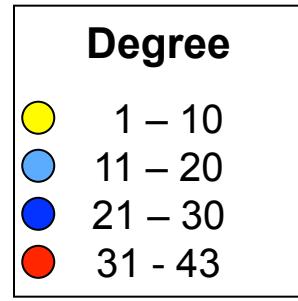
Simulated Regions



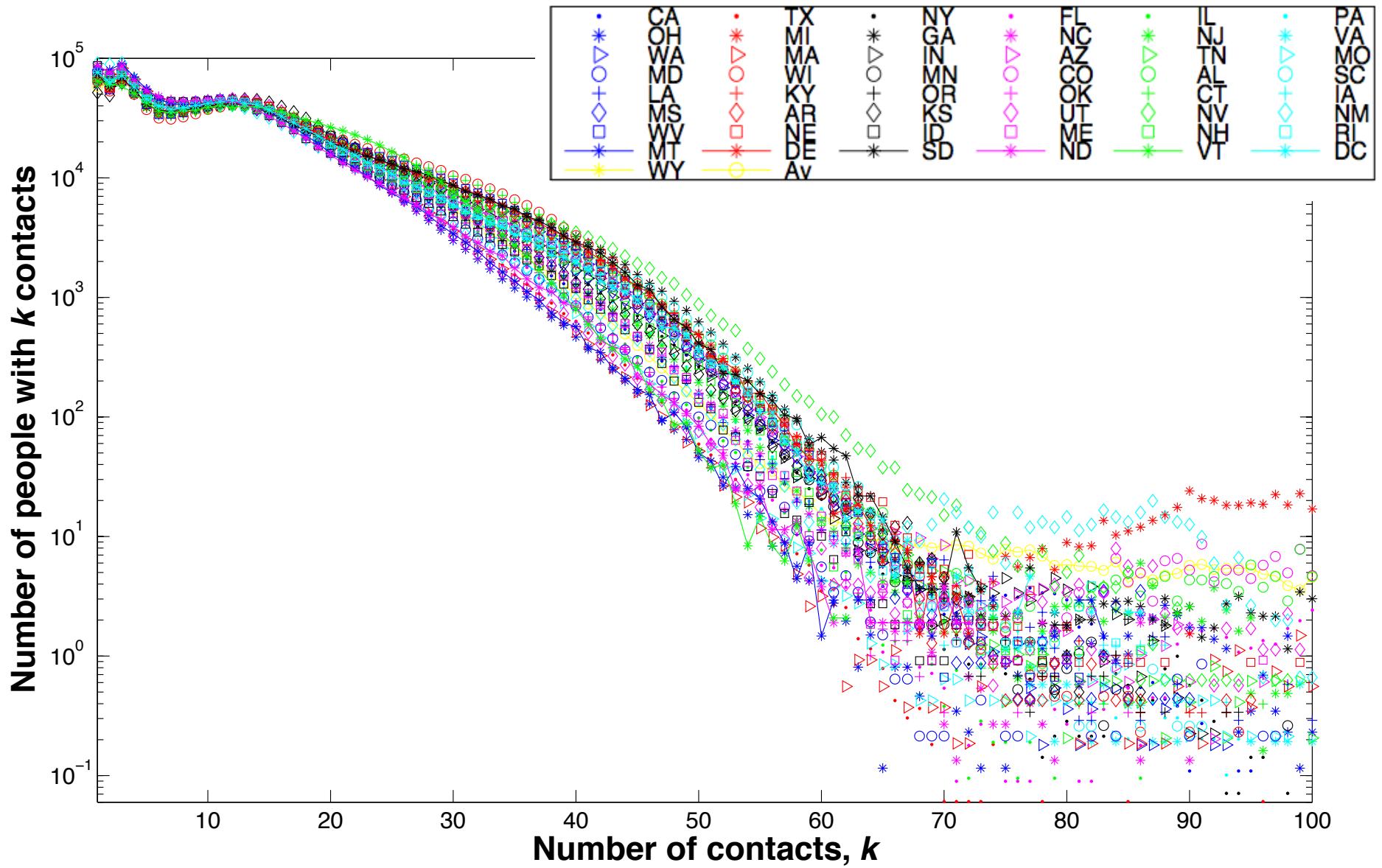
State & Regional Contact Patterns



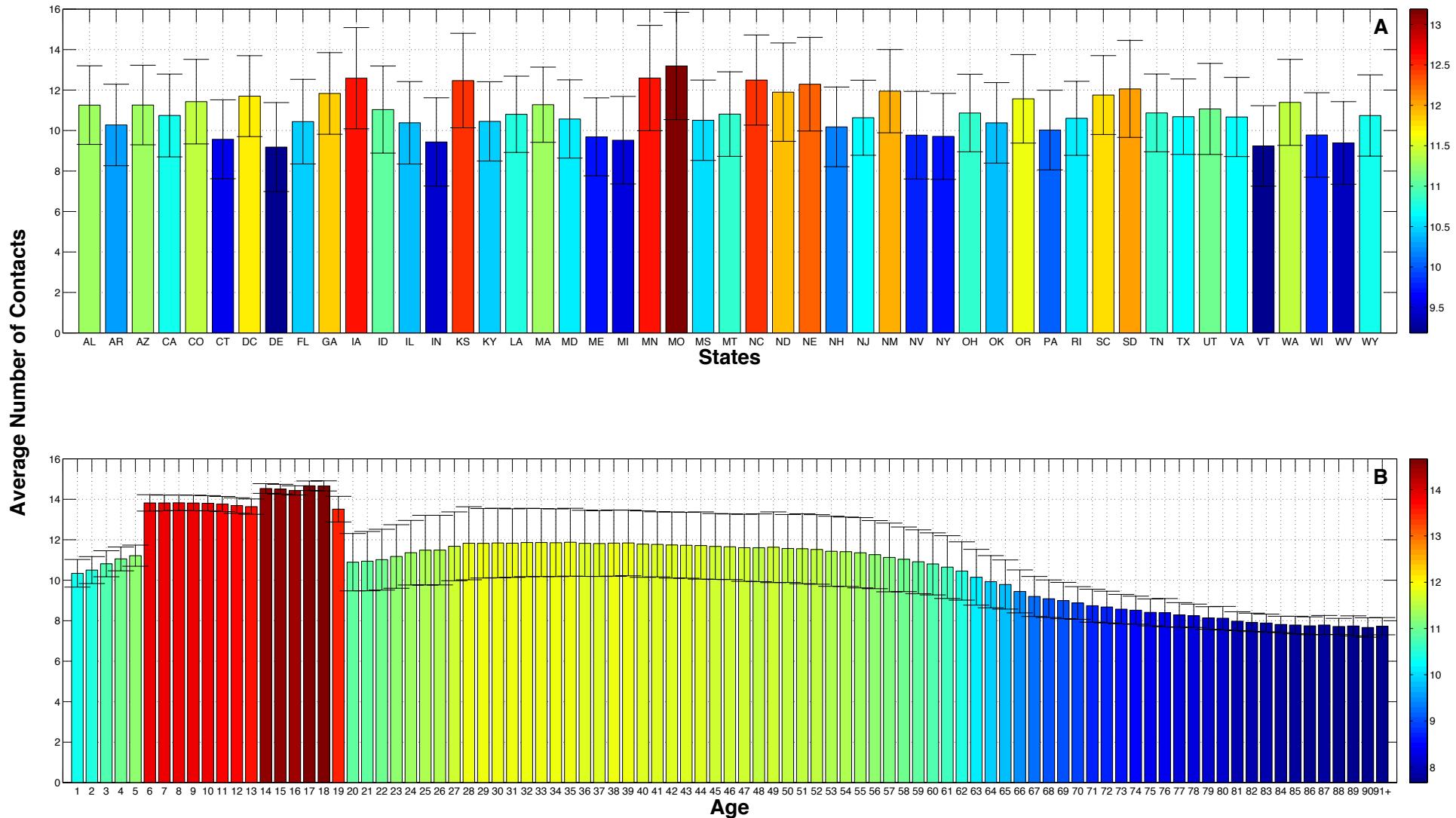
Social Contact Network Emerges – California



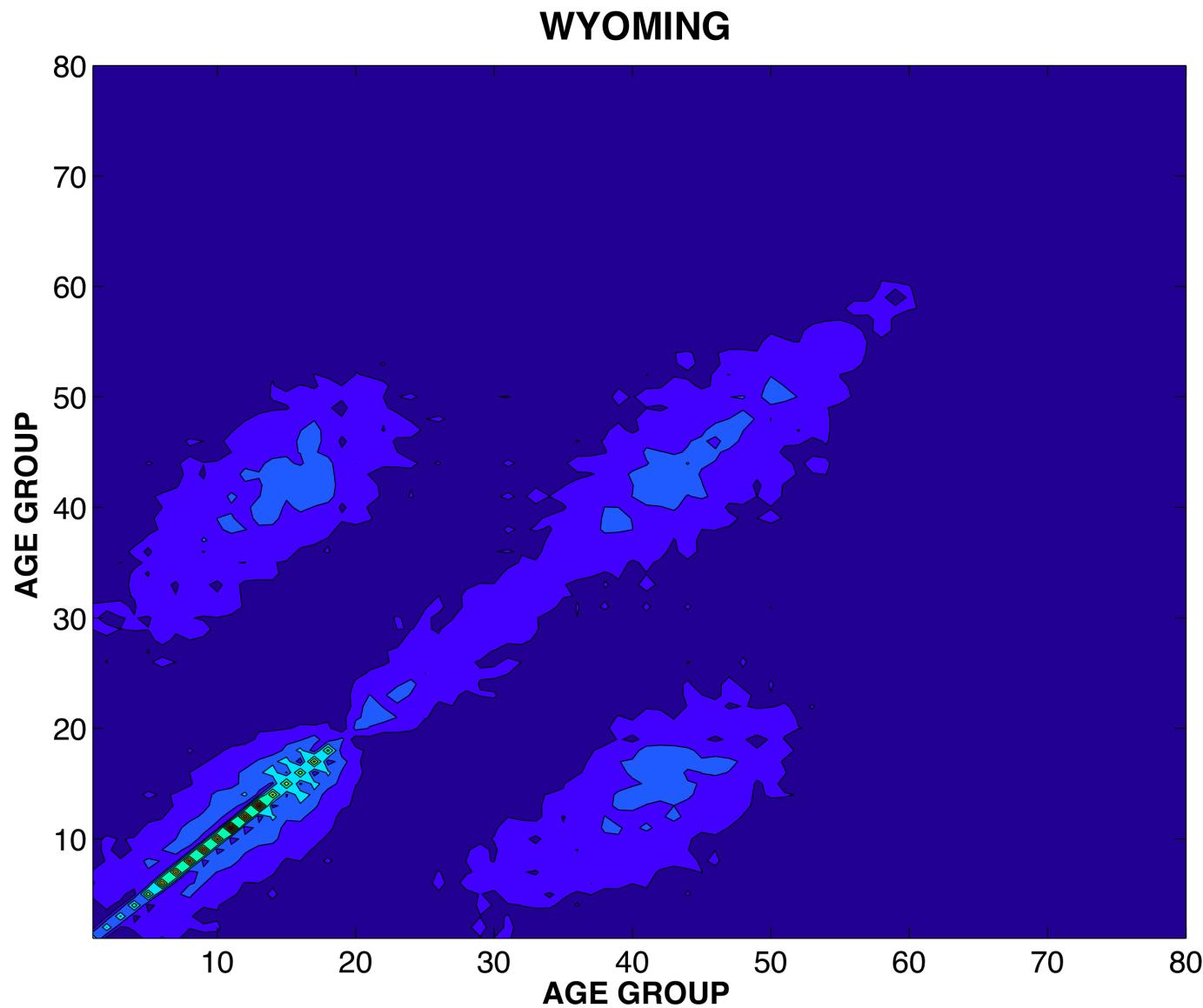
Degree Distribution



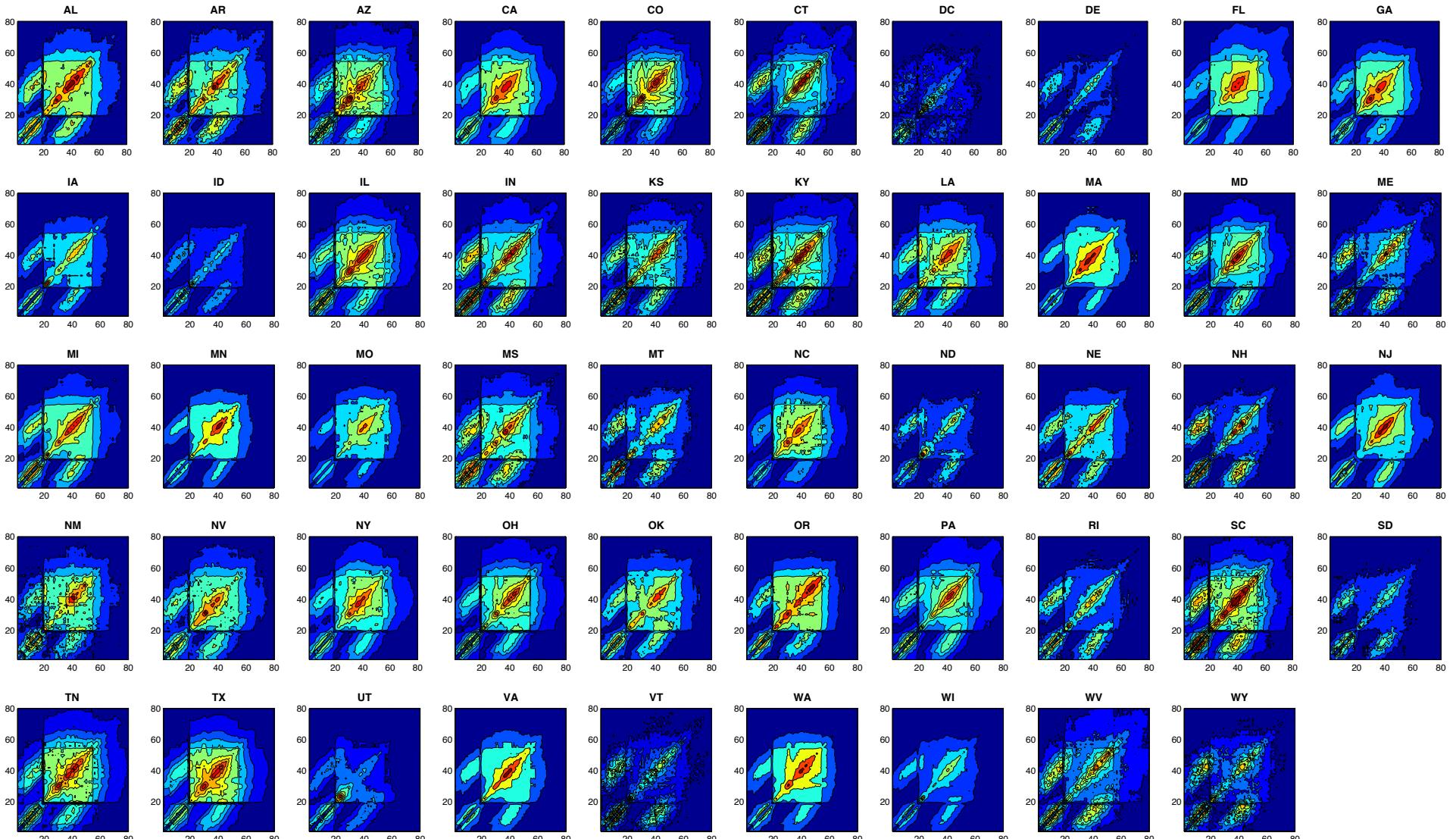
State Average Number of Contacts



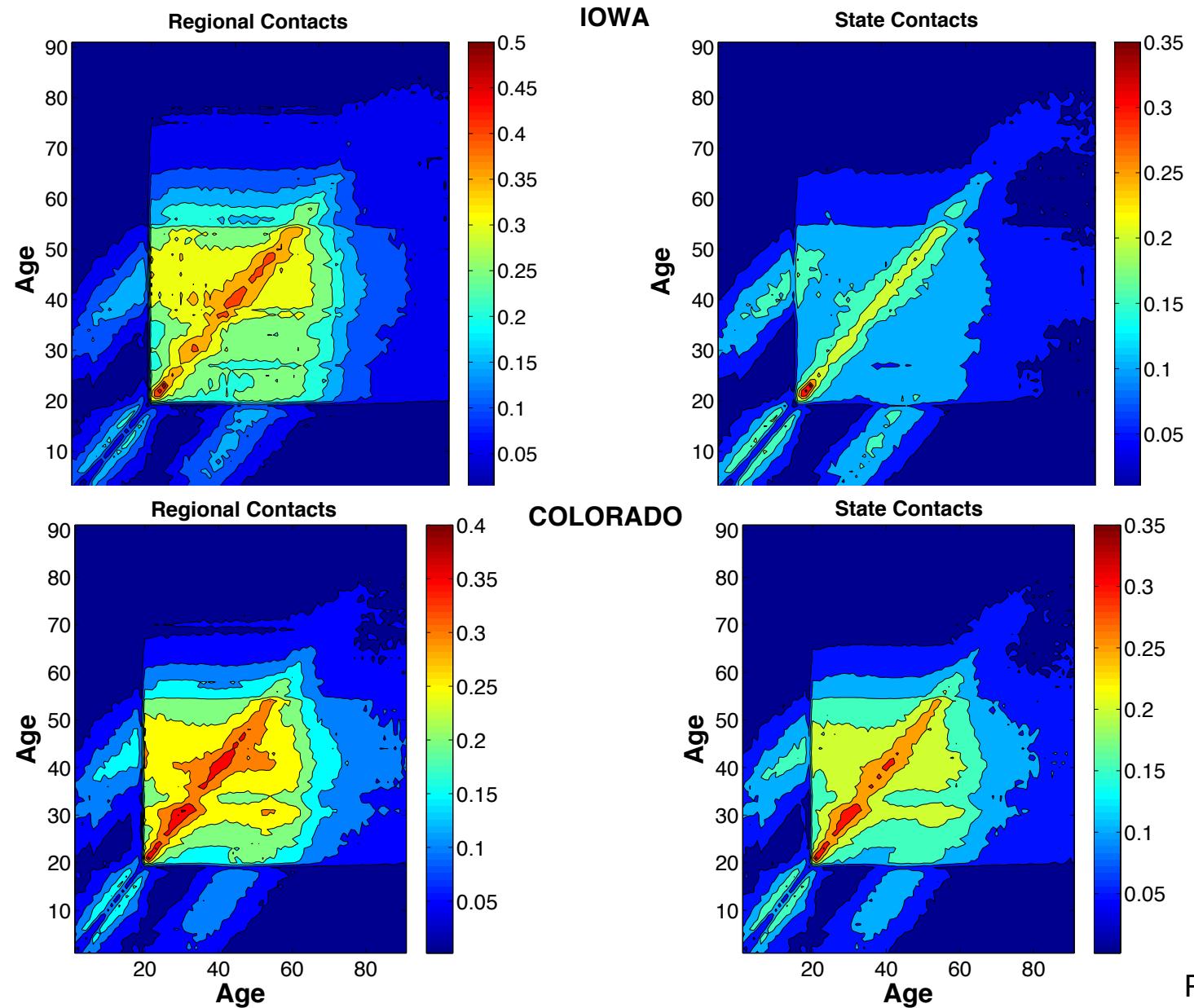
Normalized Contact Matrix



State – Total Contact Matrices

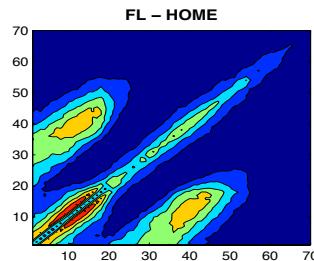


Regional vs State Contact Patterns

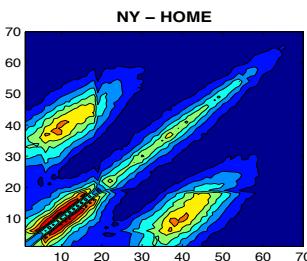


Demographic and Activity Differentiation

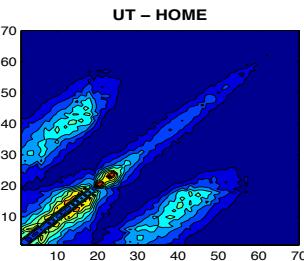
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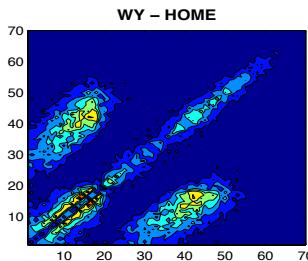
NEW YORK



UTAH

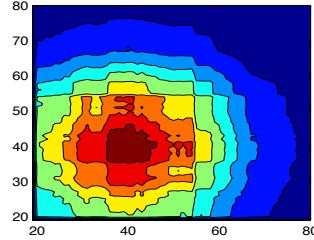


WYOMING

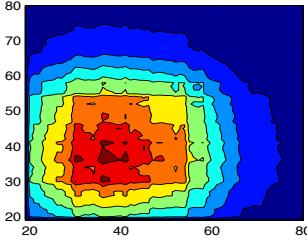


HOME

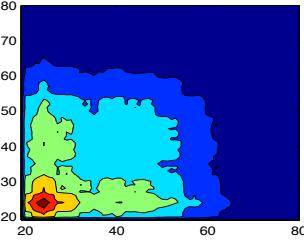
FL – WORK



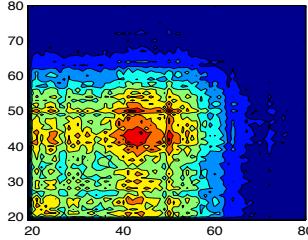
NY – WORK



UT – WORK

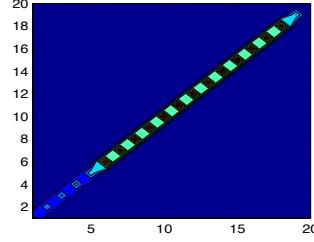


WY – WORK

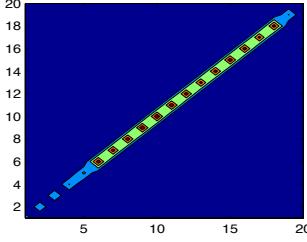


WORK

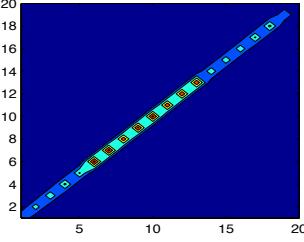
FL – SCHOOL



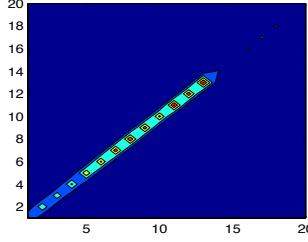
NY – SCHOOL



UT – SCHOOL

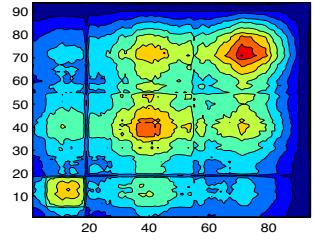


WY – SCHOOL

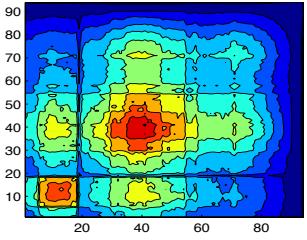


SCHOOL

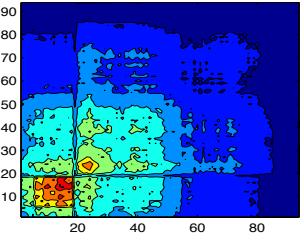
FL – OTHER



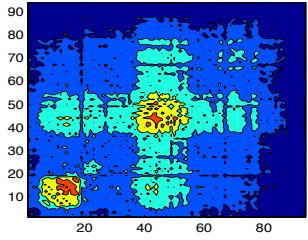
NY – OTHER



UT – OTHER

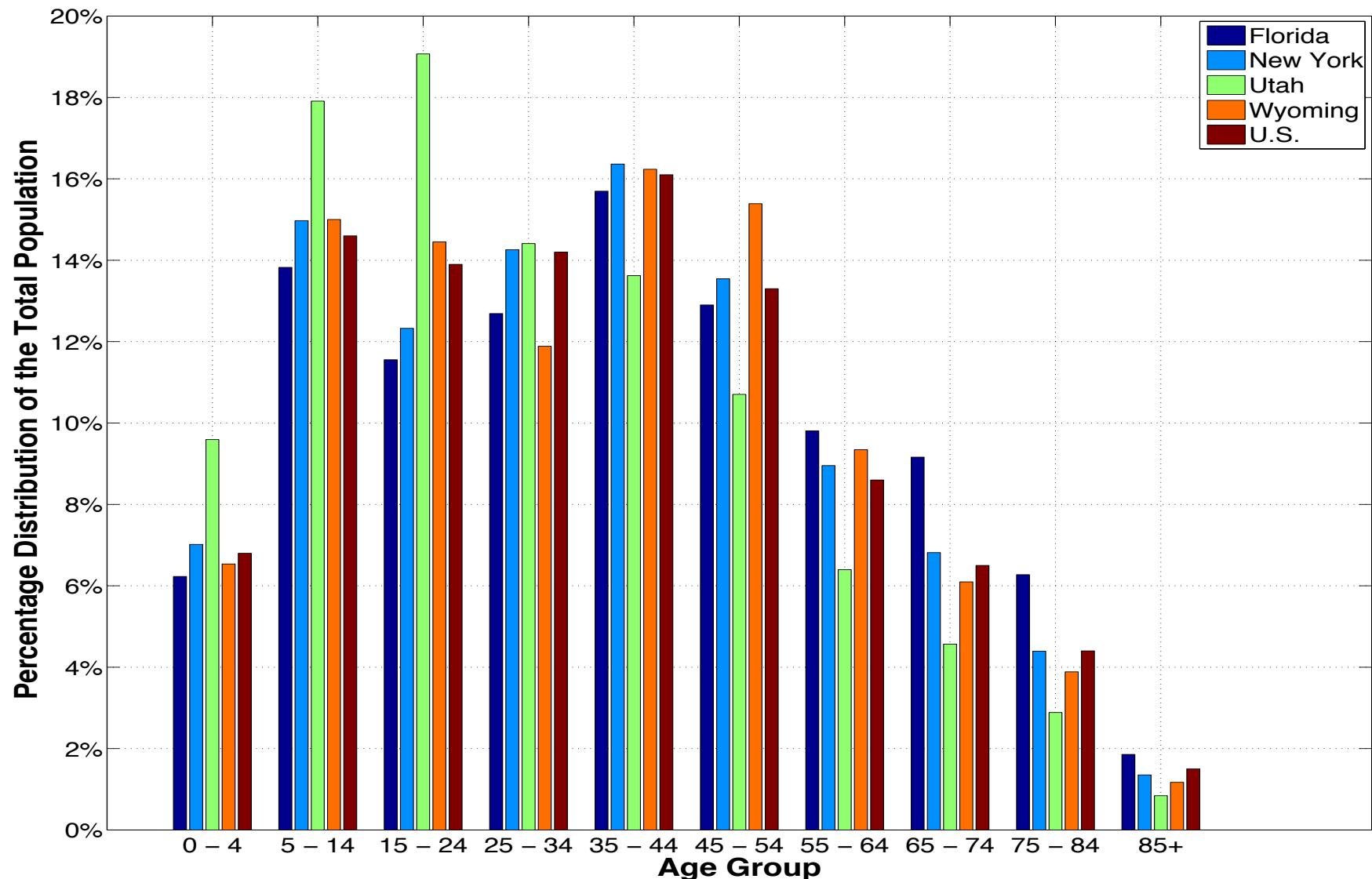


WY – OTHER

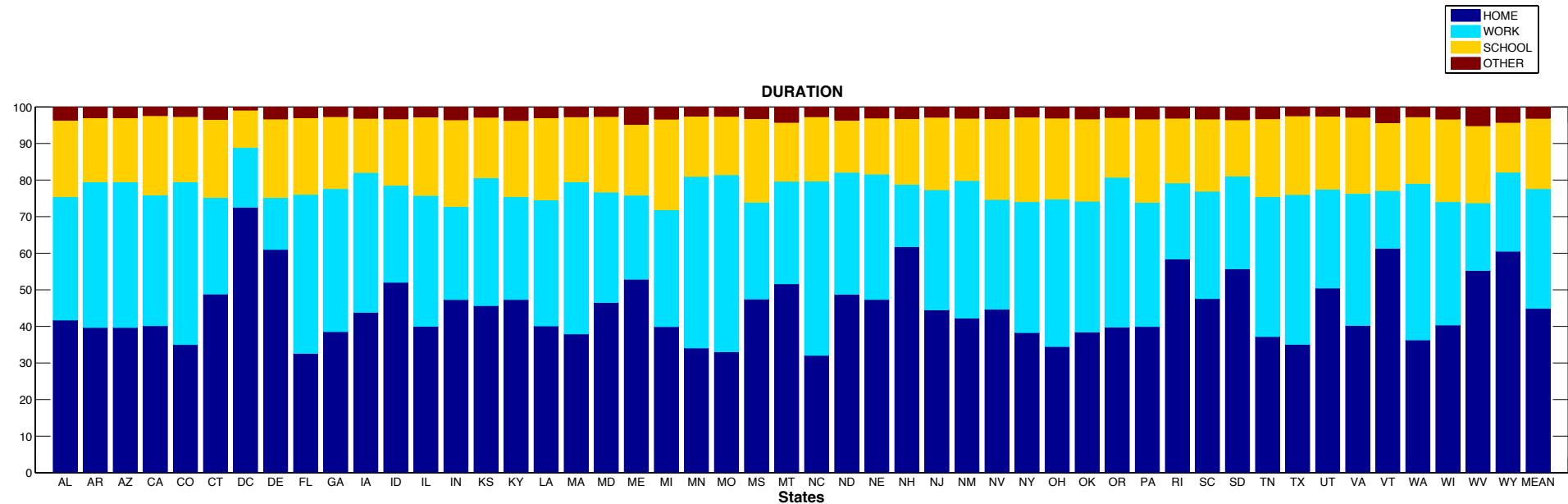
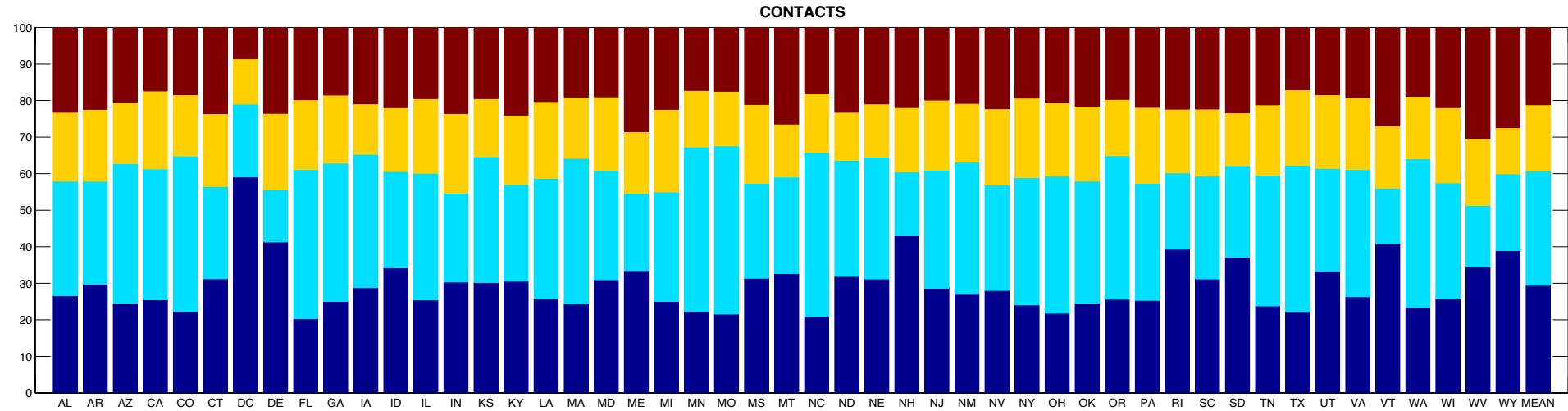


OTHER

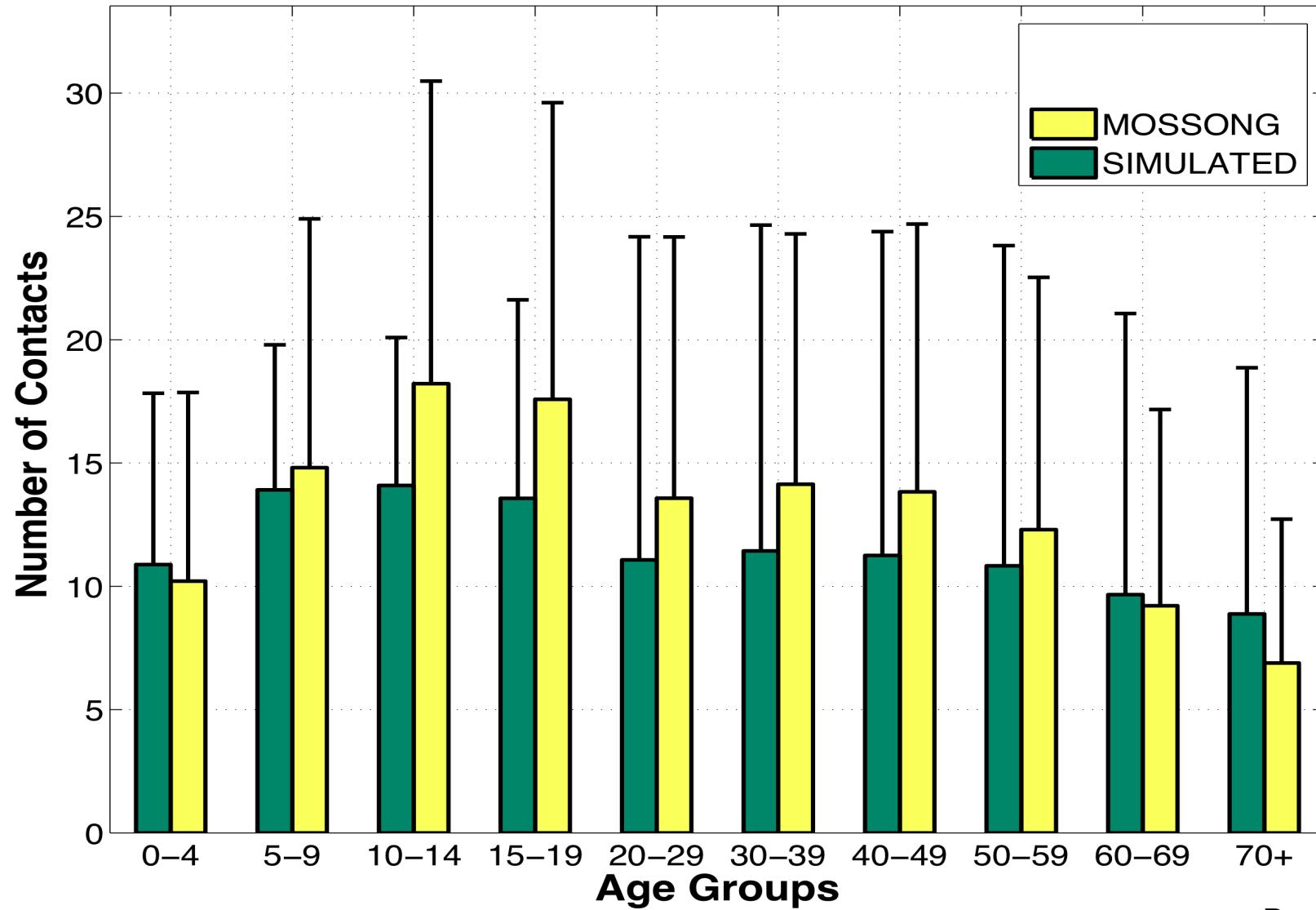
Population Age Distribution



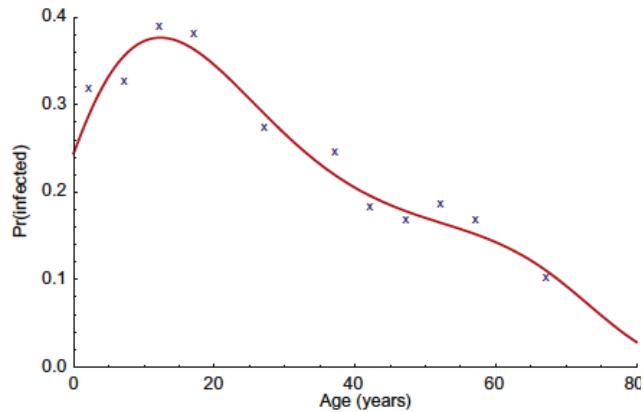
Contact and Duration Distributions



Comparison with Empirical Data

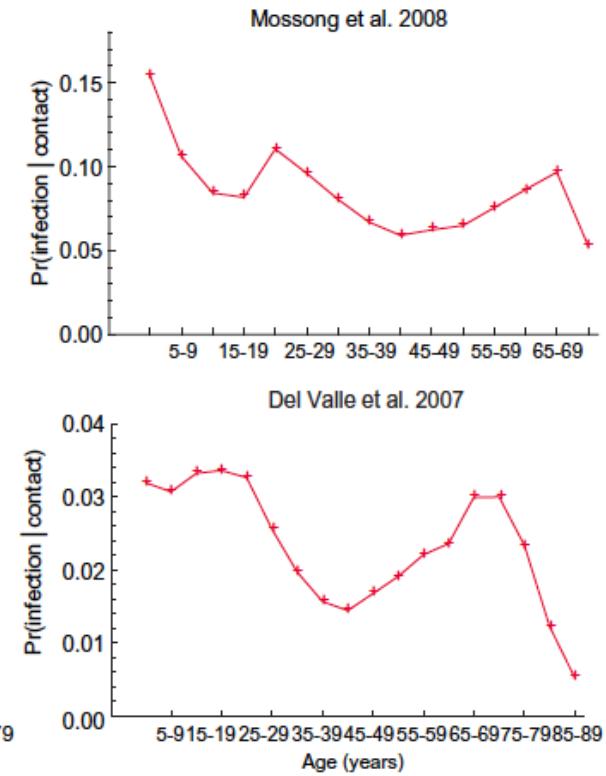
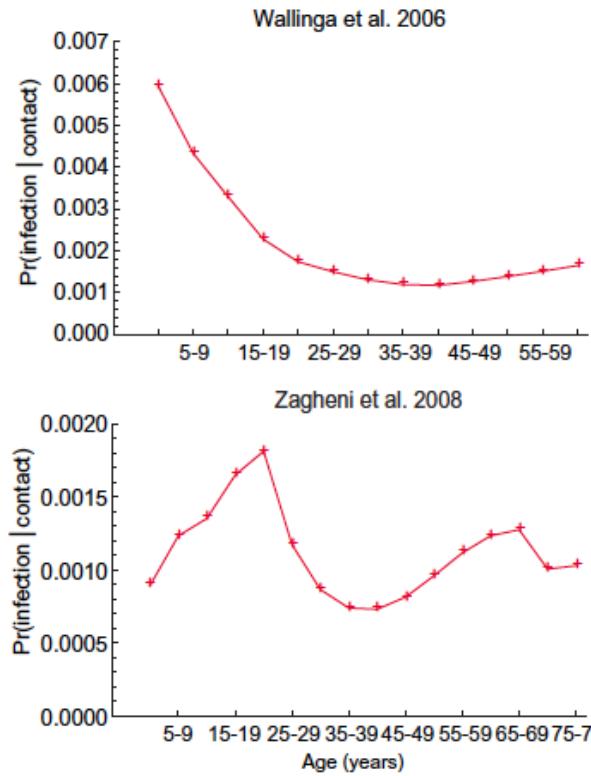


Probabilities of Infection



Household study
during 1957 pandemic

Wallinga 2006,
Mossong 2008,
Zagheni 2008,
Del Valle 2007



Summary

- Mixing patterns are important for simulating infectious disease spread
- Estimating mixing patterns can inform models and provide better disease spread projections
- Our goal is to fill the gap with agent-based simulations